LVE Substance Overview

- LVE substance is [redacted] of a JSR product formulation.
  - The JSR product is an organic resin, used in the manufacture of semiconductor devices.
- Semiconductor devices are made up of multiple layers, each with a unique pattern. The patterns are made by a process called photolithography.
- Photolithography is used to define a pattern in photoresist. In some cases the photoresist pattern is transferred into a sacrificial intermediate layers through an etch process. The intermediate layers are then transferred into the final substrate through another etch process. The photoresist and the intermediate layers do not remain on the finished article.
- The photolithography process is carried out multiple times during the manufacturing cycle, as the semiconductor devices are made up of multiple patterning levels.
- The LVE substance is used in a photoresist product.

LVE Substance Product Lifecycle

- JSR Corporation (Japan)
  - Incorporates the LVE substance in the manufacturing of the organic resin product. The product is packaged in gallon glass or plastic bottles. The bottles are packaged in a cardboard box and shipped to JSR Micro, Inc. in Sunnyvale, CA.
- JSR Micro, Inc. (Sunnyvale, CA)
  - Receives the product. Product is formulated via blending and packaged at Sunnyvale site. Use at Sunnyvale site is identified on separate use diagram. No chemical change takes place at Sunnyvale site.
- End User
  - Receives the product via air or ground transport. The product is used to manufacture an article. The product is sacrificial; it does not remain on the article. There is minimal potential worker exposure and release to the environment; this is handled via industry-standard waste disposal procedures.
- Waste Hauler
  - Incinerates solvent waste in accordance with state and federal waste disposal requirements.

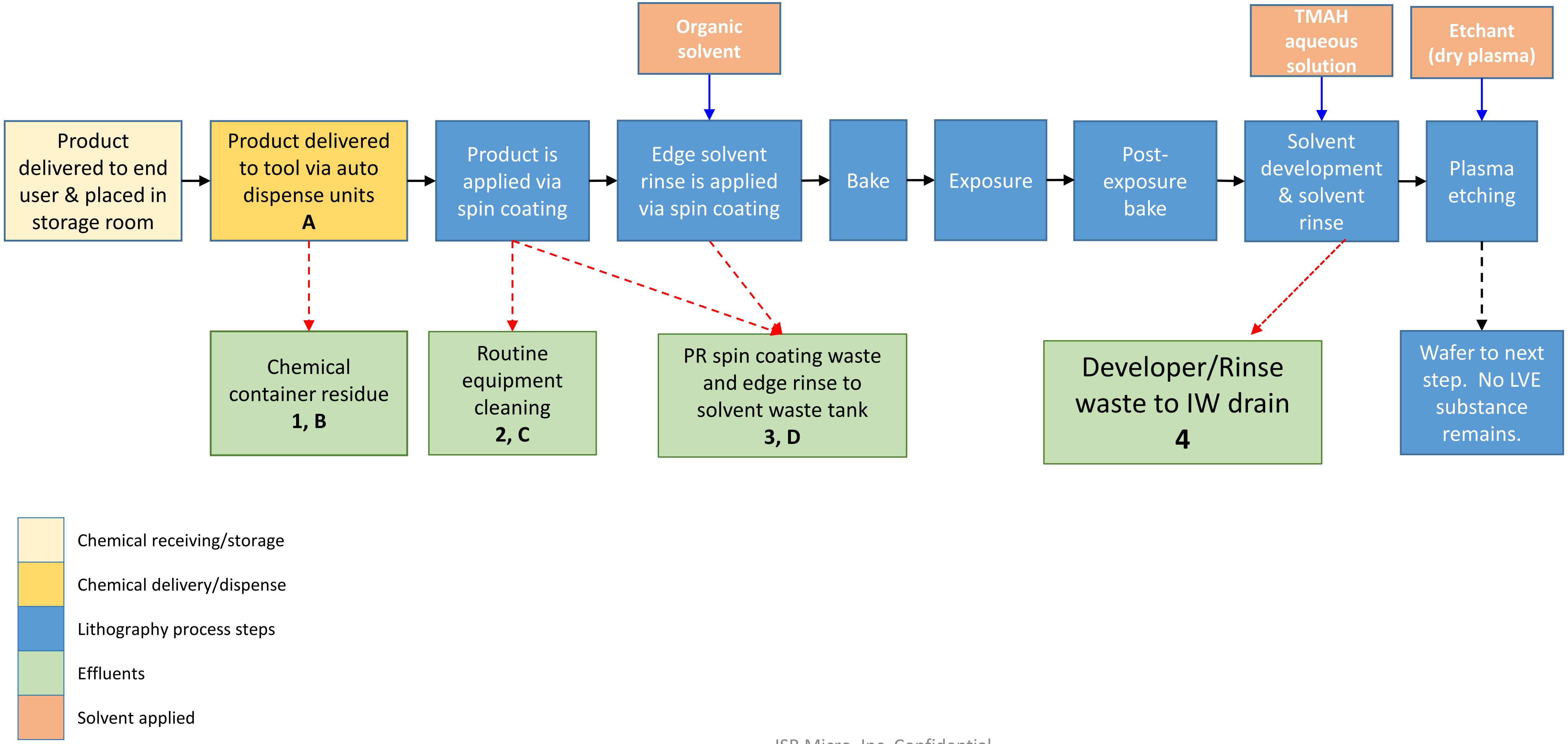
Product Delivered to Tool via Auto Dispense Units

Product is packaged in glass or plastic bottles

Product is manually connected to the probe at the Spin Coating Track

Product is automatically dispensed

Lithography Process Life Cycle for Photoresist



Product is applied via spin coating; Edge solvent rinse is applied via spin coating; Bake

Typical Spin-Coating Track

Product is applied by spin-coating in a **fully-enclosed, automated track**. Silicon wafer substrates arrive at the track in a Front Opening Unified Pod (FOUP), which is a specialized plastic enclosure designed to keep the wafers in a controlled environment. The product is automatically dispensed onto the wafers by a chemical dispense unit. Solvent is subsequently automatically dispensed onto the wafers. Solvent is evaporated via a bake step. **There is no worker exposure during the processing, as it must be performed in a clean environment.**

During the spin-coating process, 98% of the product is spun off the silicon wafer substrate. This material is collected as solvent waste, and diluted by at least 50% by other solvents used in the same track. After spin-off, subsequent solvent application and spin-off removes additional LVE substance. The solvent waste is sent off-site to be incinerated. The solvent exhaust is vented to a scrubber or thermal oxidation unit.

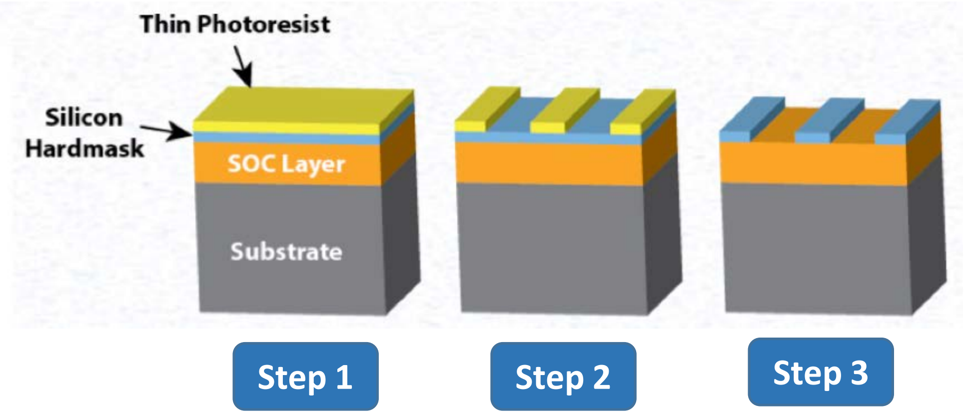
Exposure

Typical scanner

Product is exposed to UV light in a **fully-enclosed dry scanner**. Silicon wafers are automatically transferred to the exposure tool; lack of worker interaction keeps the wafers in a controlled environment. Other chemicals on the wafer undergo a chemical change as a result of exposure to UV light, but the LVE substance does not undergo a chemical change as a result of exposure to UV light. Water is applied for optical performance only. The resin is not altered or removed during this step. **There is no worker exposure during the processing, as it must be performed in a clean environment. There is no environmental emission from this step.**

Product (organic resin) is decomposed during plasma ash process

Typical Plasma Ash Tool



Apply SOC layer, silicon hardmask, and photoresist

Expose and develop photoresist

Plasma etch

The plasma ash tools are **fully-enclosed and automated**. Silicon wafers arrive at the plasma ash tool in FOUPs. Ashing is used to decompose organics by plasma. The polymer, which consists of C, H, O, is decomposed in plasma. Decomposition products are sent through thermal or chemical oxidation and/or a scrubber to form carbon dioxide and water. **There is no worker exposure during the ashing, as it must be performed in a clean environment.**

Release/Exposure Calculations

Exposures and releases based on OECD 9:

OECD Environment, Health, and Safety Publications Series on Emission Scenario Document No. 9: Emission Scenario Document on Photoresist Use in Semiconductor Manufacturing (as revised in 2010)

JSR uses the OECD calculation on daily consumption of photoresist to then calculate worker exposure.

Daily Use Rate of Photoresist [Qphoto_day (kg/site-day)] and Number of Days of Photoresist Application: [TIMEapply_days(days/yr)]:

The amount of photoresist used per day at a semiconductor manufacturing facility depends primarily upon the number of photoresist applications to wafers per hour, the amount of photoresist applied per application, and the number of application hours per day. The equation below expresses this estimation method, based on a conservative average photoresist use rate of 36 kg/site-day (representing a default value for estimating the average daily use rate of the chemical of interest (Qchem_day), which is a key parameter used in the release estimation equations.

$$Q_{photo\_day} = N_{apply} \times TIME_{apply\_hours} \times Q_{apply} \times RHO_{photo} / 1000$$

[redacted]

Daily consumption of Photoresist is estimated as [redacted]

Release/Exposure Calculations

Daily Use Rate of Chemical of Interest [Qchem_day (kg/site-day)]:

To estimate the throughput of the chemical of interest that is a component of photoresist, multiply by the chemical's concentration (weight fraction) in the photoresist. Also, facilities use multiple photoresists. The chemical of interest may not be in all of these photoresists. If appropriate, a correction factor could be applied to adjust throughput (e.g., (estimated number of photoresist applications containing the chemical of interest per wafer)/(average number of photoresist applications per wafer)). Because chemical specific use information is not available or not known, the conservative default value for this correction factor is 1.

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$$Q_{chem\_day} = Q_{photo\_day} \times F_{chem} \times \frac{N_{app\_chem}}{N_{app\_photo}}$$

[redacted]

The concentration is based on the current recipe.

Daily consumption of the LVE substance is estimated as [redacted]

Environmental Release: 1
Chemical Container Residue to Incineration

Container Residue:
(Release No. 1)

Photoresist is typically supplied to the user in small containers, including 1-gallon (4-liter) bottles and 2.5-gallon (10-liter) NOW Pack bottles with a collapsible internal bladder. Potential releases occur from cleanout and/or disposal of the used container. JSR assumes that up to 0.6% of the liquid originally in small containers remains as residual after unloading. All used containers are incinerated.

The daily release rate of the photoresist chemical of interest (kg/site-day) from container residue can be calculated using the equation below. At the default daily use rate of photoresist of 36 kg/site-day, there are multiple bottles used per day. For this reason, the release rate is daily and the fractional loss rate may be applied to the daily use rate.

$$Elocal_{container\_residure\_disp} = Q_{chem\_day} \times F_{container\_disp}$$

[redacted]

Container residue of the LVE substance is estimated as [redacted]

Environmental Release: 2
Routine Equipment Cleaning to Incineration

Residual from Equipment Cleaning
(Release No. 2)

Most facilities use various solvents to clean process equipment. As a default, it is assumed that 1% of the daily use rate of photoresist, and therefore also of the chemical of interest, less the container residue, is released from cleaning. This release is expected to be sent to incineration.

The daily release rate of the photoresist chemical of interest (kg/site-day) in this step can be calculated using the equation below.

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$$Elocal_{equip\_disp} = Q_{chem\_day} \times \left(1 - F_{container\_disp}\right) \times F_{equip\_disp}$$

[redacted]

Routine equipment cleaning of this RM is estimated as [redacted]

Environmental Release: 3
Resist spin coating waste and edge rinse to solvent waste tank

Application Excess (Spin-off)
(Release No. 3)

The photoresist is applied by a dispensing apparatus while the wafer is spinning at high speed in an exhausted enclosure. The excess photoresist from the application process is collected from the enclosure and disposed to incineration. This generic scenario assumes that a default range of 1% to 7% of the dispensed photoresist containing the chemical of interest remains on the wafer, and that the remaining "spun-off" material is disposed. Some of this excess photoresist remains in the equipment and is disposed as cleaning residue, and this amount is excluded from the application excess.

The daily release rate of the photoresist chemical of interest (kg/site-day) in this step can be calculated using the equation below. The calculation assumes that the amount of resist remains on the wafer is 1% (the worst case scenario).

$$Elocal_{excess\_disp} = Q_{chem\_day} \times \left(1 - F_{container\_disp}\right) \times \left(1 - F_{equip\_disp}\right) \times \left(1 - F_{photo\_wafer}\right)$$

[redacted]

Resist coating waste/edge rinse waste of this RM is estimated as [redacted]

Environmental Release: 4
Developer and rinse waste to IW drain

Residual in Developer
(Release No. 4)

Developer solutions are a potential source of release of the chemical of interest. The developer solution is designed to remove either the exposed (positive) or unexposed (negative) photoresist from the wafer. The developer with removed photoresist is expected to be released to the facility's industrial waste water treatment system, and then to a publicly owned treatment works for further treatment. It is estimated that 50% of the photoresist adhered to the wafer is removed in the development process. Some of this photoresist remains in the equipment and is disposed as cleaning residue, and this amount is excluded from the loss from this source.

The daily release rate of the photoresist chemical of interest (kg/site-day) in this step can be calculated using the equation below.

$$Elocal_{developer} = Q_{chem\_day} \times \left(1 - F_{container\_disp}\right) \times \left(1 - F_{equip\_disp}\right) \times F_{photo\_wafer} \times F_{photo\_develop}$$

[redacted]

Developer and rinse waste of this RM is estimated as [redacted]